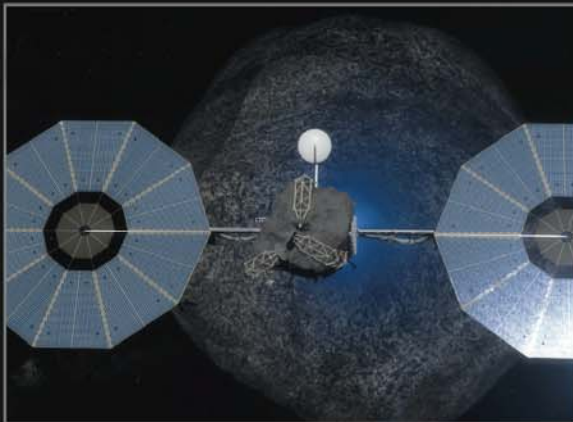
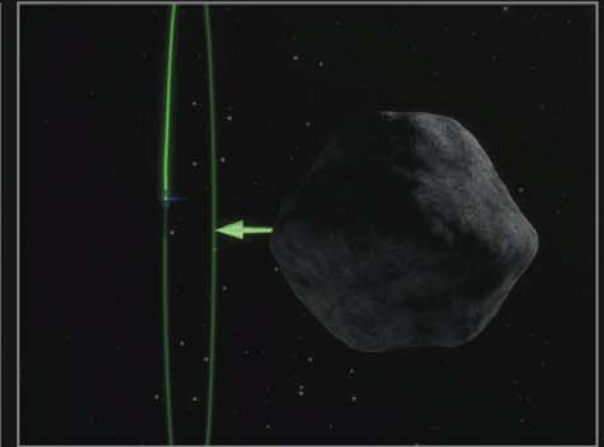


# Asteroid Redirect Mission: EVA and Sampling Activities



13 Meeting of the NASA Small  
Bodies Assessment Group

June 29 2015

Paul Abell – NASA JSC  
Steve Stich – NASA JSC

# Presentation Outline



- **Asteroid Redirect Mission (ARM) Overview**
  - Notional Development Schedule
  - ARV Crewed Mission Accommodations
- **Asteroid Redirect Crewed Mission (ARCM) Mission Summary**
- **ARCM Accomplishments**
- **Sample collection/curation plan**
  - CAPTEM Requirements
- **SBAG Engagement Plan**

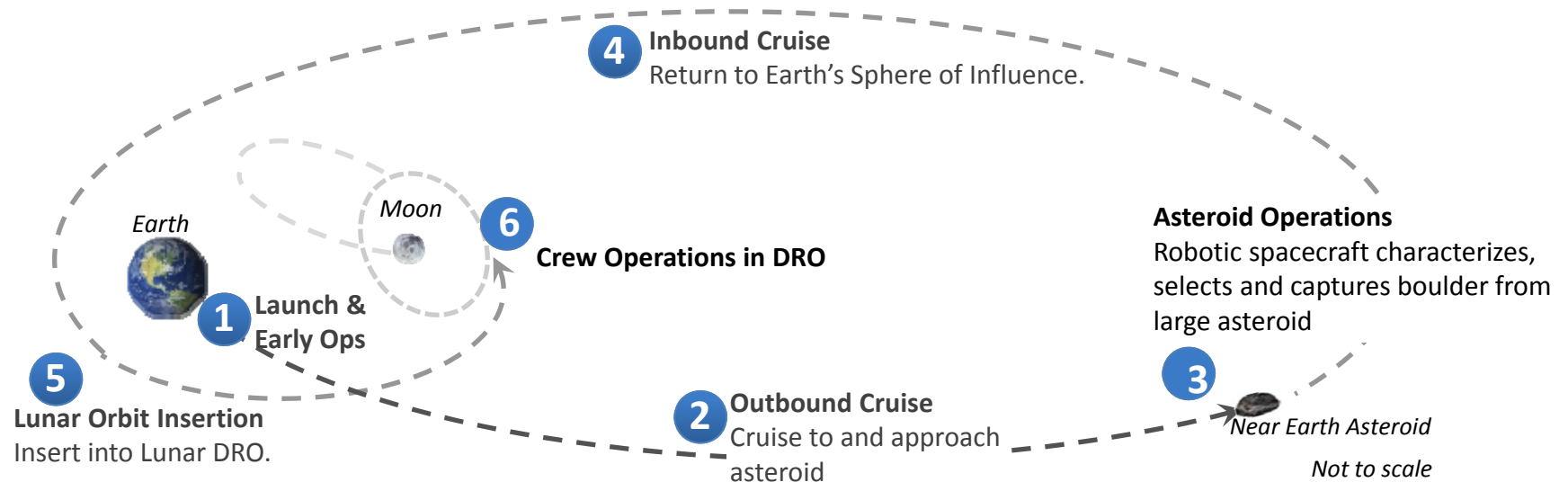
# Objectives of Asteroid Redirect Mission



1. **Conduct a human exploration mission to an asteroid in the mid-2020's, providing systems and operational experience required for human exploration of Mars.**
2. Demonstrate an advanced solar electric propulsion system, enabling future deep-space human and robotic exploration with applicability to the nation's public and private sector space needs.
3. Enhance detection, tracking and characterization of Near Earth Asteroids, enabling an overall strategy to defend our home planet.
4. Demonstrate basic planetary defense techniques that will inform impact threat mitigation strategies to defend our home planet.
5. Pursue a target of opportunity that benefits scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.



# Asteroid Redirect Mission (ARM) Overview



- **Asteroid Redirect Robotic Mission (ARRM) Launch Date: December 2020**
  - During the Inbound Cruise phase (4), the ARV will image the boulder providing context for EVA planning.
  - Based on boulder data, EVA operations and sample collection tools will be finalized during this time (2023)
  - Asteroid is returned to a crew accessible orbit in 2025
- **Asteroid Redirect Crewed Mission (ARCM) Launch Date: December 2025**
  - 2 Crew, 26\* day mission
  - Crew will conduct 2 four-hour EVAs to collect up to 100kg\*\* of sample materials.

\*Based on current mission design parameters

\*\* Including sample containers

# Crewed Mission Objectives - Guiding Principles

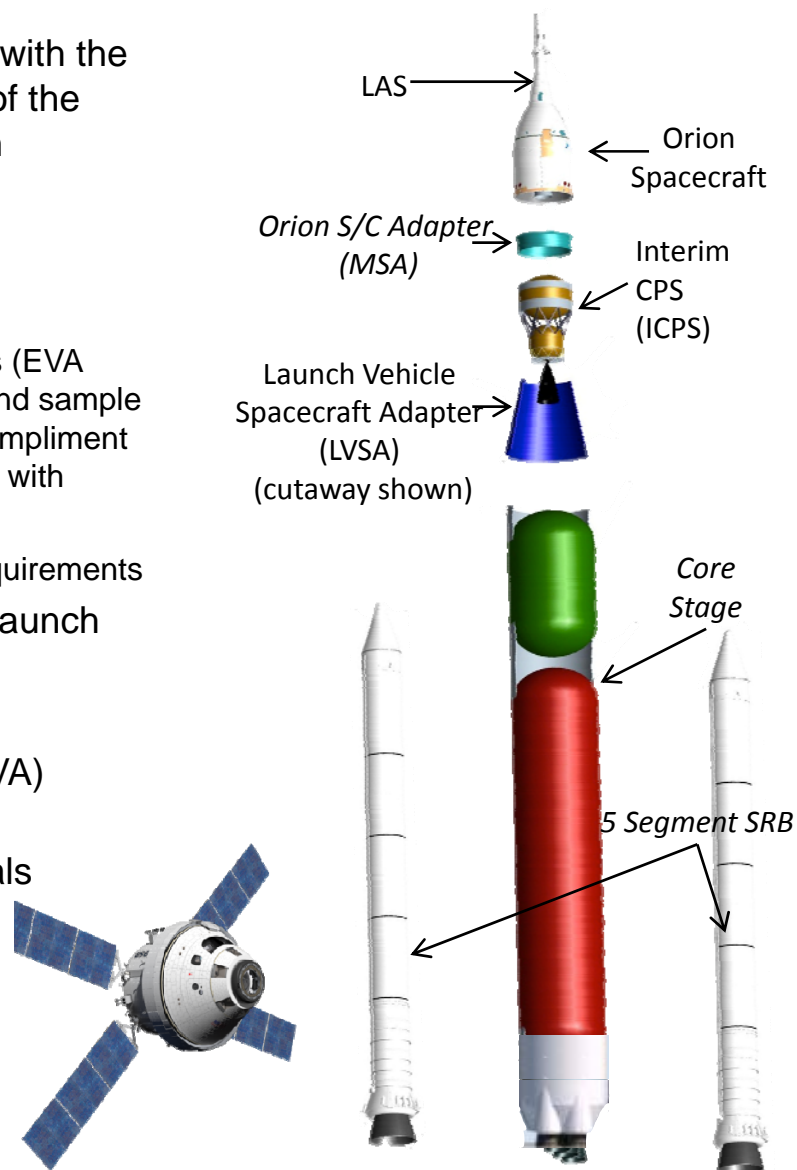


## ■ Mission Objectives

- Orion will provide capability for the crew to rendezvous with the Asteroid Redirect Robotic spacecraft extract a sample of the asteroid and return the sample and crew safely to Earth

## ■ Guiding Principles

- Minimize changes to Orion EM-2 Configuration
  - Provide additional Orion mission capability with add-on kits (EVA capable suits, Docking Mechanism, rendezvous sensors and sample collection equipment). To accommodate kit mass, crew complement reduced to 2 for ARCM, EVA limited to 4 hrs, sample mass with containment limited to 100 kg.
  - All performance analysis based on SLS/Orion Baseline requirements
- Utilize existing SLS Block I Configuration for the Orion launch vehicle
- Affordability key consideration in every design trade
- Utilize robotic spacecraft for Extra-Vehicular Activity (EVA) augmentation (e.g. tool stowage, handholds)
- Provide capabilities that enhance future exploration goals
- Manifest consistent with planning and budget guidance

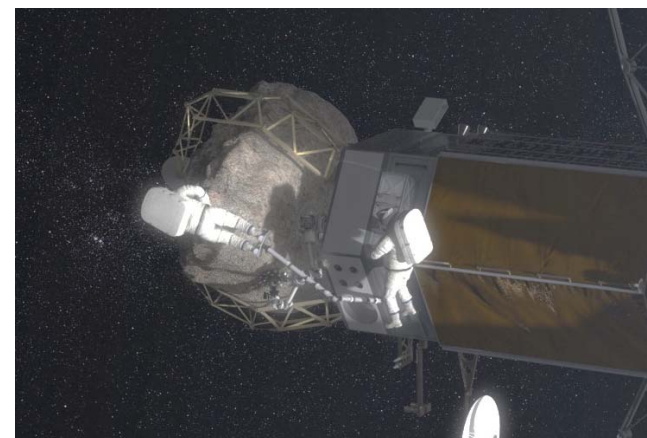
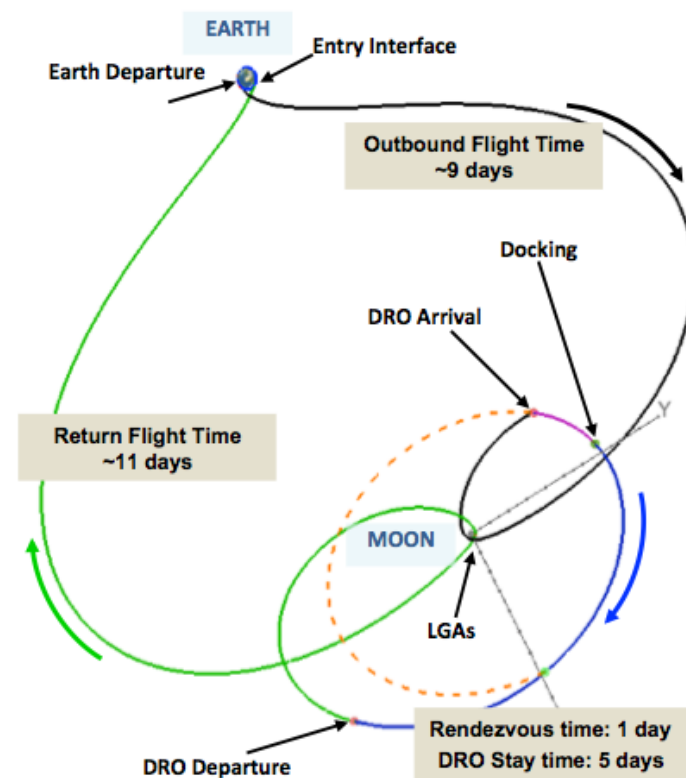




# December 2025 Reference Crewed Mission Overview



- Orion launch with 2 crew members via Block 1 Space Launch System
- Use Lunar Gravity Assist (LGA) trajectories for outbound and Earth return.\*
- Total mission duration 26 Days with 5 days docked with Asteroid Return Vehicle (ARV).<sup>+</sup>
- Two person crew launched aboard Orion.
- Rendezvous/dock with ARV in ~71,000 km Distant Retrograde Orbit above lunar surface.
- Conduct 2 four-hour EVAs using adapted Modified Advanced Crew Escape Suits (MACES) to observe, document, and collect asteroid samples.
- DRO ops for 5 days: one day for rendezvous, one day for each EVA, one day in between EVAs and one day for undock/contingency
- Orion returns to Earth on an LGA trajectory, with a skip targeted return near San Diego, CA

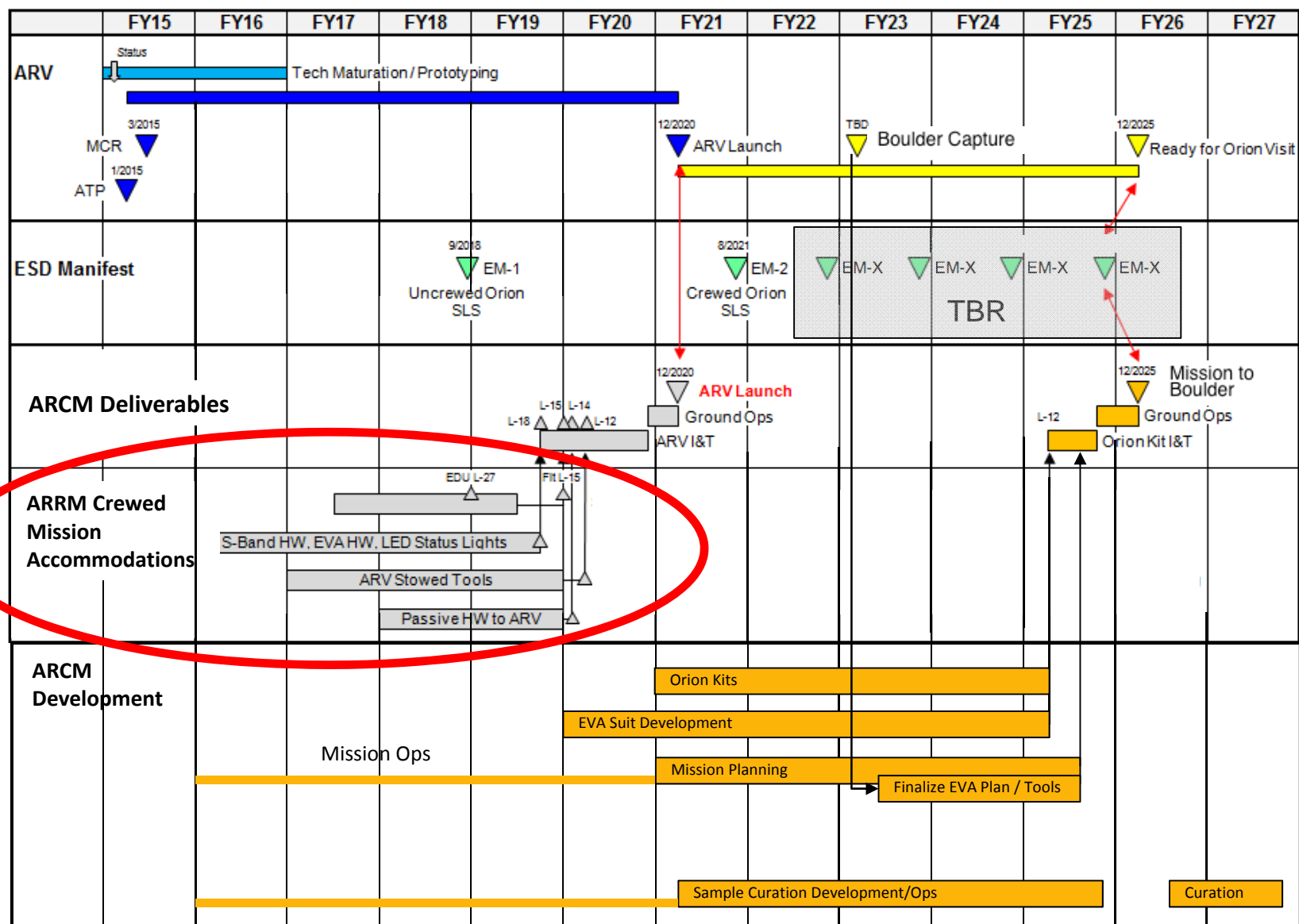


*\*LGA Flight days shown represent one possible trajectory.*

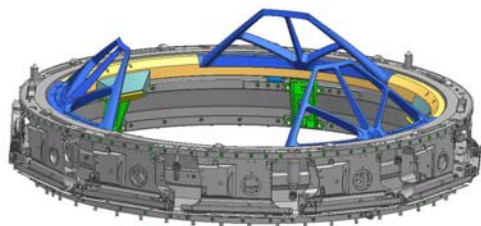
*Other trajectories may require additional flight days.*

*<sup>+</sup>Orion Consumables allow for a 30 day total mission duration.*

# ARM Proposed Schedule



# ARRM Crewed Mission Accommodations (Docking)



## IDSS IDD-Compliant Docking Mechanism

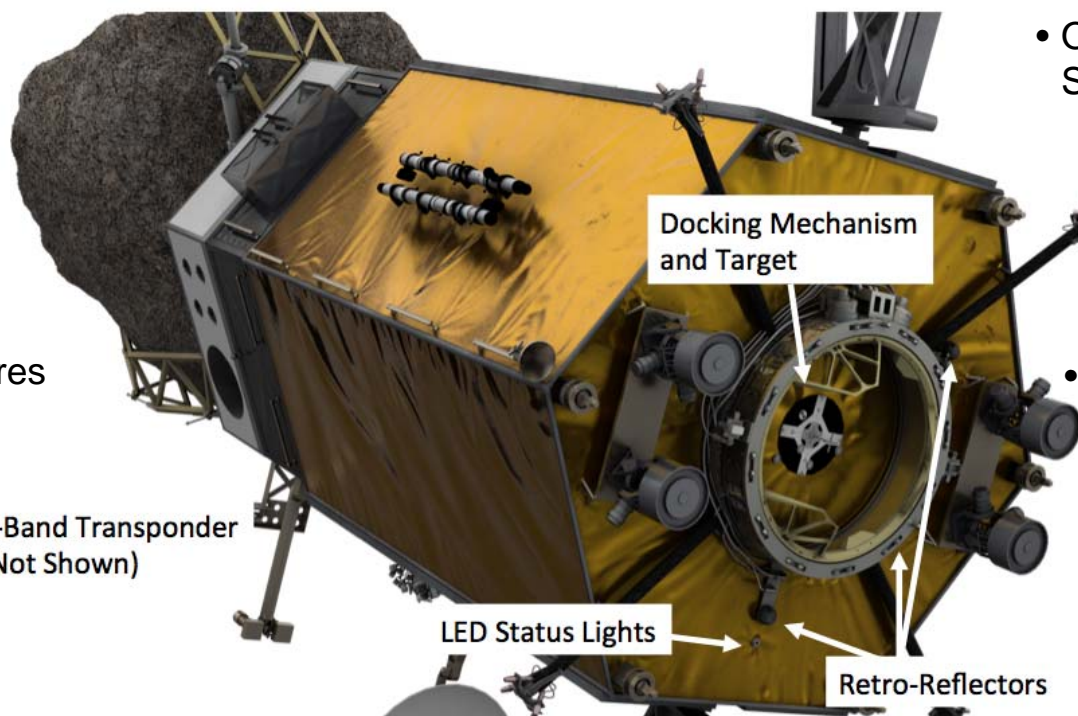
Passive docking mechanism on ARRM  
(active mechanism on crewed vehicle)



## Docking Target

- Augmented with features for relative navigation sensors
- Visual cues for crew monitoring

S-Band Transponder  
(Not Shown)



## Power and Data Transfer

- Power and data connectors integrated into the docking mechanism.
- Data transfer used during ARCM
- ARRM power transfer is available for future missions.



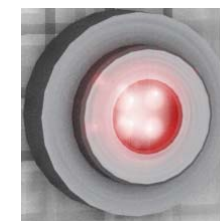
## Rendezvous Aid

- Orion-compatible low-rate S-band transponder



## Retro-Reflectors

- Tracked by the LIDAR during rendezvous and docking



## LED Status Lights

- Indicate the state of the ARRM systems, inhibits and control mode

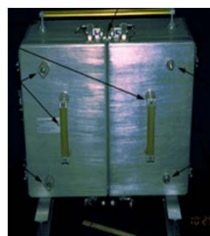


# ARRM Crewed Mission Accommodations (EVA)



## EVA Telescoping Booms

- Telescoping Booms for positioning the EVA astronaut on the boulder (~3 m in length)



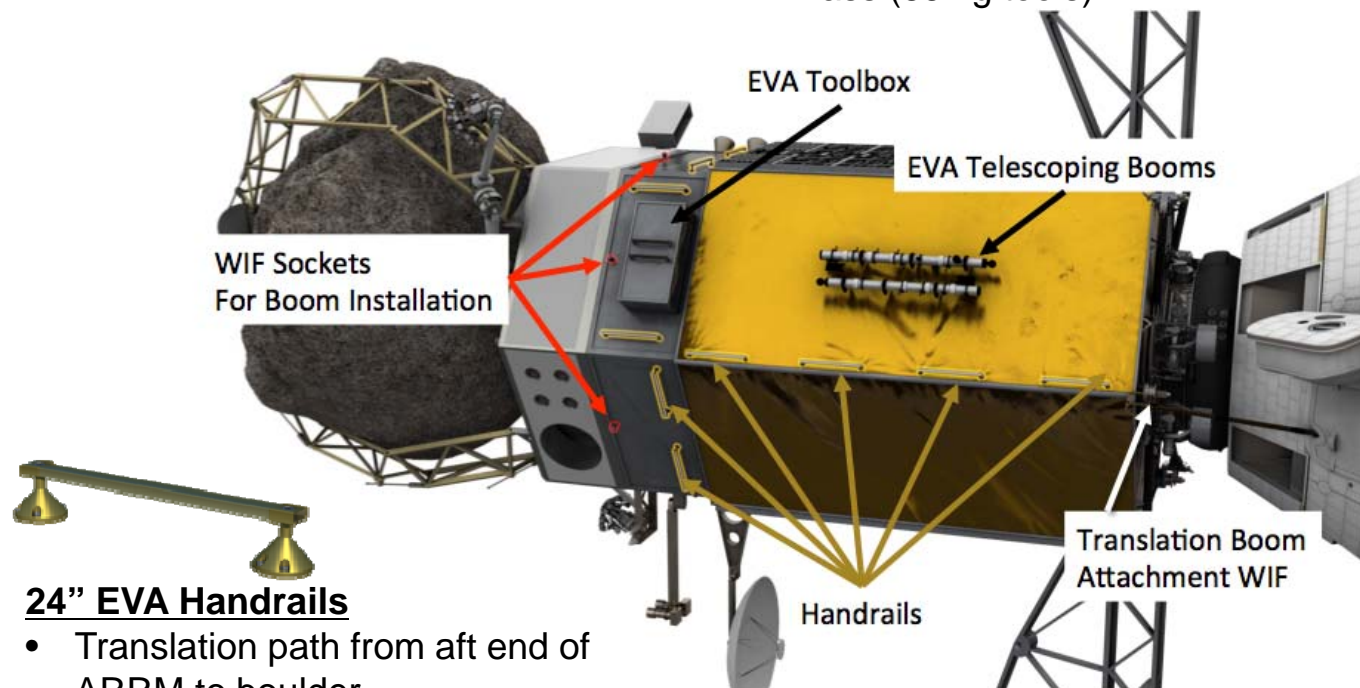
## EVA Tool Box with tools

- Tool box to offset Orion mass (85 kg tools)



## Worksite Interface (WIF) Sockets

- Provide boom attach points to ARRM.



## 24" EVA Handrails

- Translation path from aft end of ARRM to boulder
- Ring of handrails around the Mission Module near the boulder

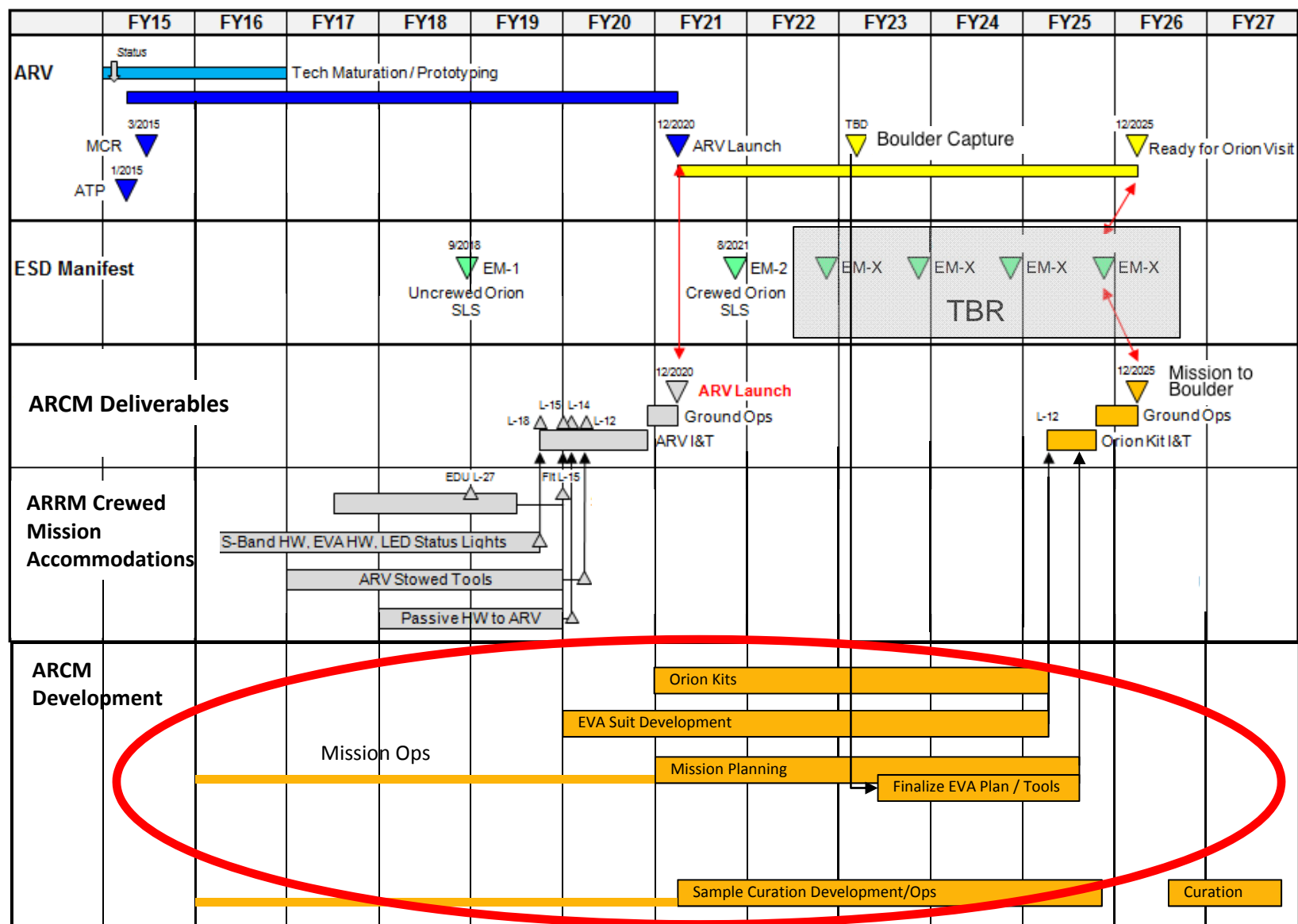
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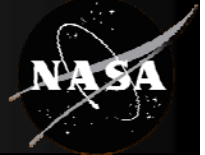
## Crew Safe Certification

- Spacecraft designed for Crew Safety including EVA kick loads, sharp edge, safety inhibits and Caution and Warning annunciation.

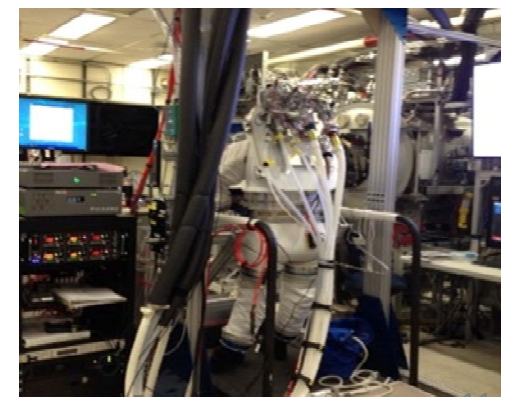
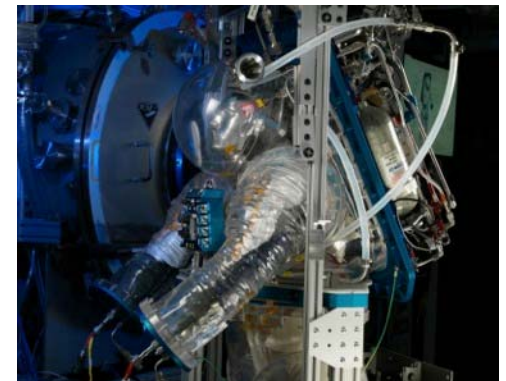
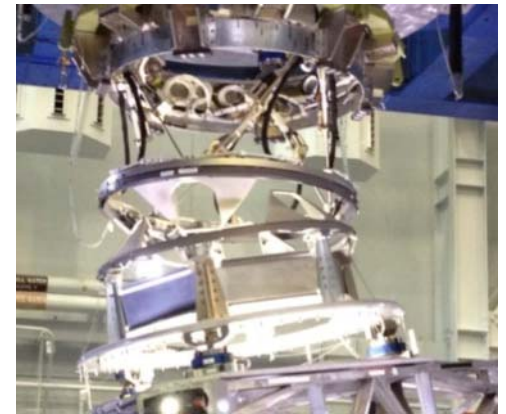
# ARM Notional Schedule



# Asteroid Redirect Crewed Mission (ARCM): Progress



- Completed feasibility testing series in Neutral Buoyancy Laboratory to evaluate EVA techniques and modifications in launch and entry suit (MACES) mobility
- Determined existing and matured AR&D sensors can meet specification for common sensor suite
  - Concept study contracts completed by Ball Aerospace and Boeing
- Significant Progress on NASA Docking System Block I
  - 90+% drawings have been released in CDR Phase
  - Component development testing
  - Successful 6 Degree of Freedom testing at JSC for a wide variety of contact conditions and vehicle masses
- Completed Portable Life Support System (PLSS) 2.0 integrated testing primary objectives
  - Full integrated test system with human metabolic simulator
  - Integrated system performed as designed
- PLSS/Mark-III Prototype Suit Human-in-the-Loop Testing





# Space Suit Feasibility Prototype Testing Modified Advanced Crew Escape Suit (MACES)



Lab, Zero G, ARGOS tests



MACES EVAs are demonstrated as feasible and neutrally buoyant testing is warranted

Neutral Buoyancy Lab Series #2 – 5 tests (2, 3 and 4 hours long)



Task complexity increases while improvements are made to the suit including Extravehicular Mobility Unit gloves, drink bag, etc. Need for improved stability and work envelope

Initial NBL testing has shown feasibility of doing many asteroid retrieval sampling tasks using a MACES. Continued testing with a variety of crew member sizes, along with incremental suit and tool enhancements is critical in order to validate the concept.

2013

2014

May

June

July

August

Sept

Oct – Jan

February

March

April

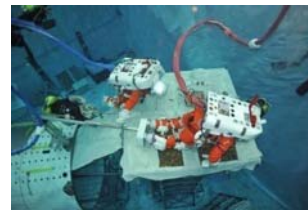
May

NBL Series #1 – 3 tests (2 hours long)



Established NBL Interface, ability to weigh-out the suit, and the subject's ability to use the suit underwater.

NBL Series #3 – 5 tests (4 hours long)



Evaluation of mobility enhancements, improved worksite stability, and testing on higher fidelity capsule mockups with tools culminating in a full ARCM EVA timeline.

Hardware and  
Procedure  
Improvements

Improved weights

EMU Gloves

Added tool  
harness

Drink bag included

New liquid cooling  
garment

Mobility  
Enhancements

Dual Suit Ops

EMU Boots

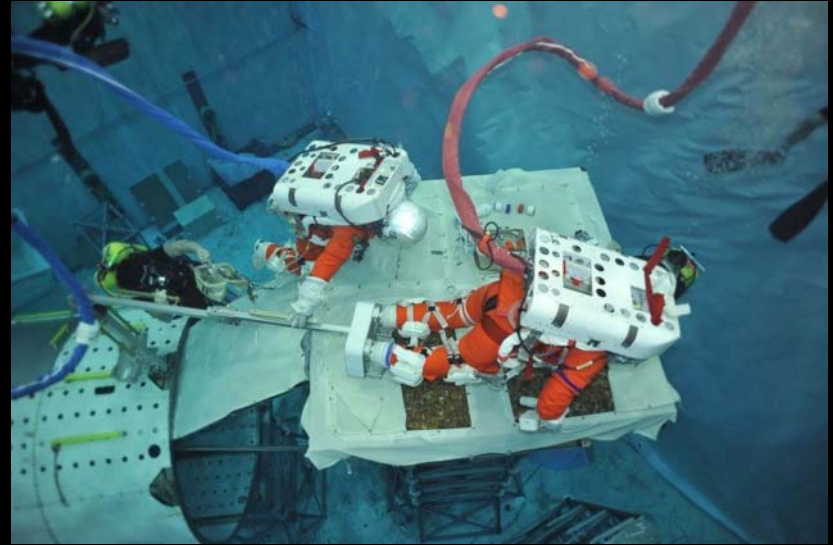
Portable Life Support System Mockup

Body Restraint  
Tether

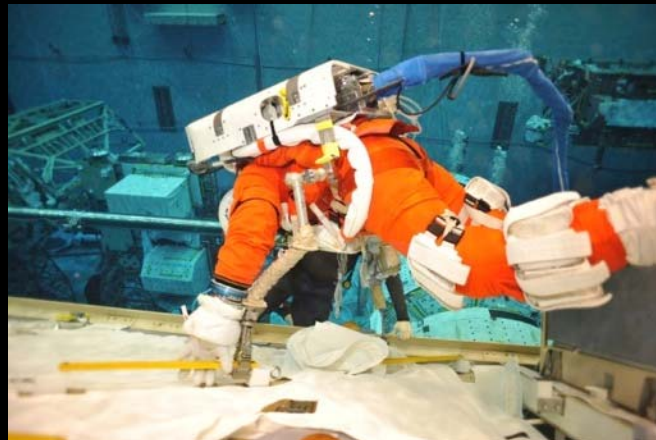
# EVA Feasibility Testing Worksite Stabilization in Neutral Buoyancy Laboratory



Adjustable Portable  
Foot Restraint  
operations were  
tested and execution  
is very similar to the  
ISS Extravehicular  
Mobility Unit



Body Restraint  
Tether allowed  
the crew to  
perform two  
handed task

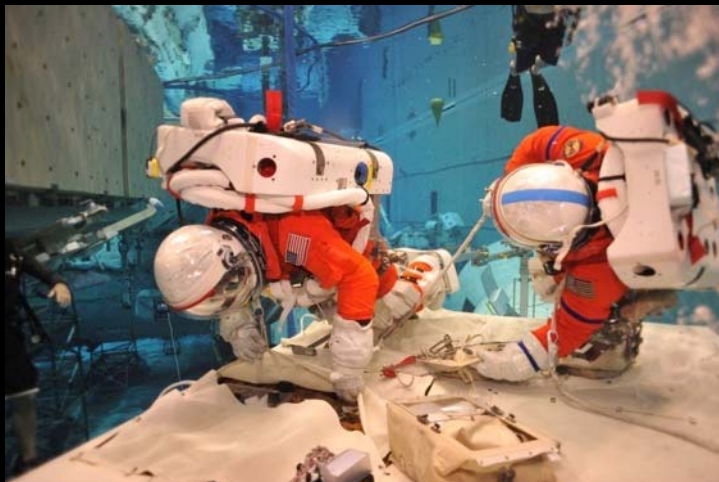
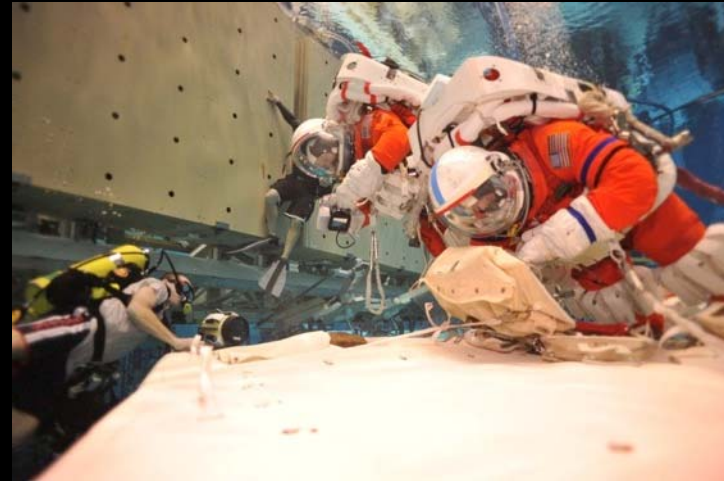
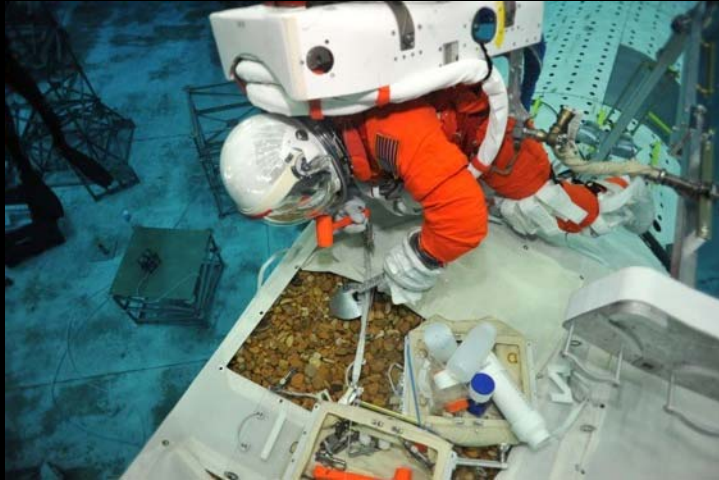




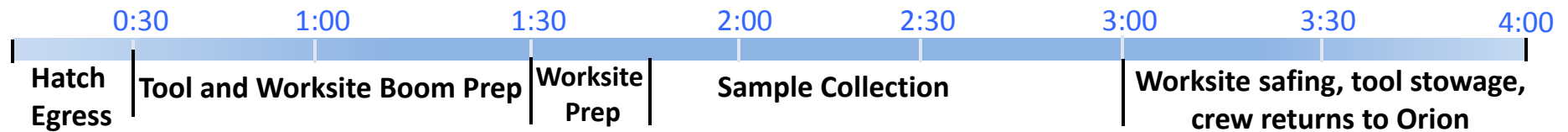
# EVA Feasibility Testing Sampling Tasks in Neutral Buoyancy Laboratory



Crew was able to perform several examples of sampling tasks including worksite imaging, float sample collection, hammer chiseling and pneumatic chiseling.



# ARCM EVA Timeline Estimate in Hours

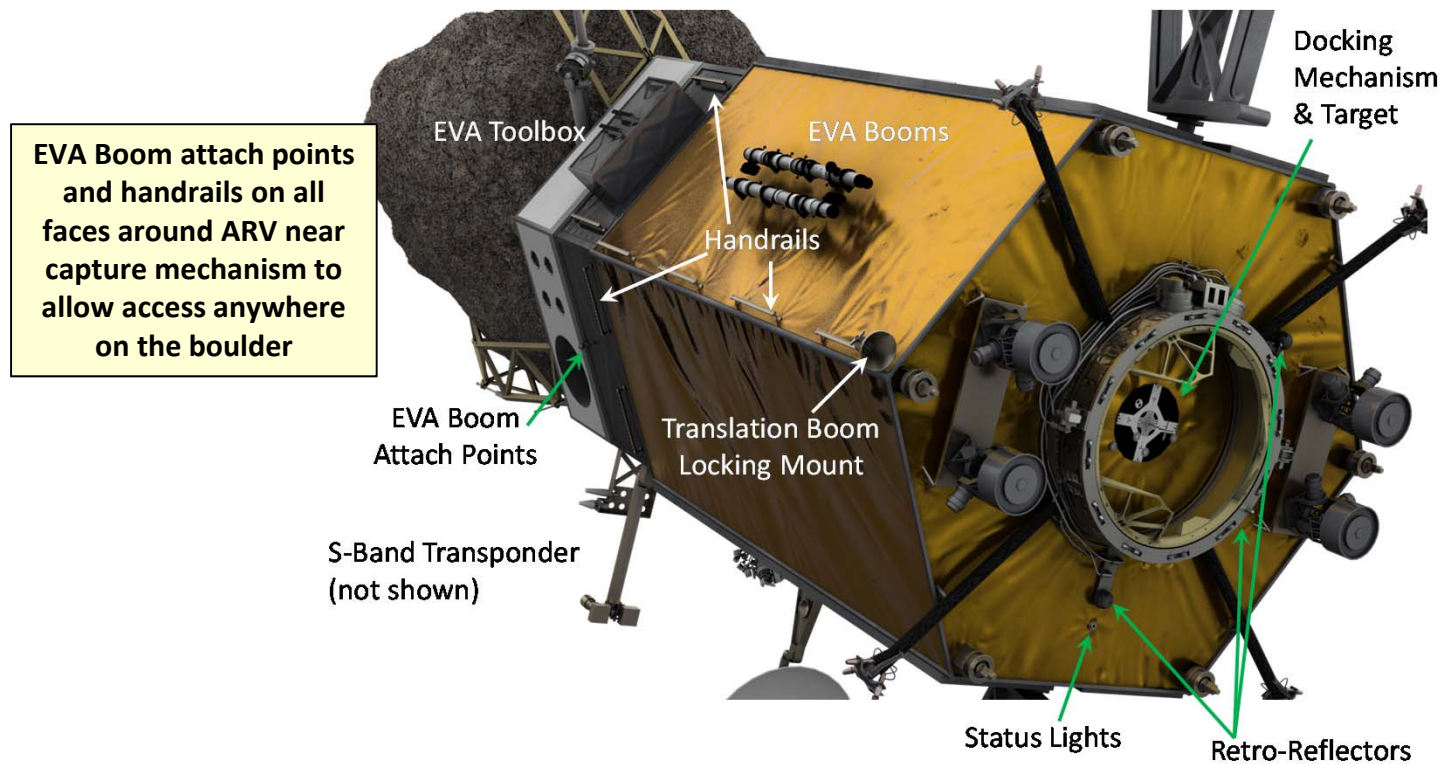


- Prior to each EVA, the Orion rotates the stack to place the sample site into a thermally favorable location.
- The EVA commences when the Orion hatch is open and the crew is operating on the Exploration PLSS. Boulder specific sampling tools and containers are carried out of Orion.
- The Crew will deploy EVA communication antenna and a translation path between the Orion and the ARRV using a telescoping boom launched with Orion.
- Using the translation aids mounted to the ARRV, crewmembers make their way to the EVA toolbox located on the ARRV.
- The crew will deploy the telescoping booms with integrated foot restraints stowed on the ARRV and collect EVA tools pre-deployed in the EVA toolbox.
  - The boom is attached to ARRV using pre-integrated boom socket located on the ARRV.
  - The sample retrieval worksite is chosen in conjunction with the science and EVA communities based on sample value and ease of collection.
- Sample collection activities are conducted and samples placed in appropriate containment for stowage in Orion
- Worksite is made safe, basic EVA tools are stowed, and the crew returns with sample containers to Orion

# EVA Sample Collection



- The robotic spacecraft contains WIF sockets located around the perimeter of the mission module near the captured boulder. Crewmembers can attach the EVA booms to the WIF sockets to reach virtually any sample location on the boulder (except under the Contact Restraint System (CRS) legs for crew safety).
- Options are being evaluated for possibly retrieving the geologic context samples collected by the touchdown pads on the CRS legs.





# Backup